Investigations on the photosynthetic productivity of some newly selected grapevine varieties

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Summary: Investigations were carried out on the photosynthetic productivity of 5 wine varieties which had been selected at the Institute of Viticulture and Enology: Storgoziya, Nikopolski mavrud, Pomoriïski biser, Dunavska gamza and Dunavski lazur. The first of them was grafted on Chasselas x Berlandieri 41 B rootstock, each of the others was on three rootstocks: Chasselas x Berlandieri 41 B, Berlandieri x Riparia SO 4, and (Berlandieri x Riparia Kober 5 BB) x (Rupestris Martin) III-102 D.

For all varieties, the leaf dry matter per unit leaf area was greatest when they were grafted on III-102 rootstock. During the vegetation period, the specific leaf weight increased, but the rate of dry matter accumulation in leaves was not constant and gradually decreased with time.

The content of pigments and the leaf area per vine were greatest on SO 4 rootstock. On this rootstock, the highest yield was obtained for all cultivars mainly at the expense of the grape cluster weight. The thickness of the trunk under the graft-union, though, was smallest and an irregular increase of the diameters of the two components, rootstock and scion, occurred.

Key words: rootstock, scion, variety of vine, grafting, photosynthesis, chlorophyll, yield, production, phenology, statistics, Bulgaria.

Introduction

In our previous investigations (SLAVCHEVA 1981, 1988; STOEV and SLAVTCHEVA 1982) the effect of the most important ecological factors – light, temperature, carbon dioxide, soil humidity – and of some agricultural factors – training systems, planting density – on the photosynthetic rate of grapevine was shown. Our efforts have recently been directed to investigating physiological and biochemical peculiarities of grapevine plant in relation to variety and also choice of rootstock. This is aimed at facilitating selection of perspective grapevine varieties with optimum parameters of leaf photosynthesis and with valuable agrobiological characteristics, as well as at utilizing the obtained knowledge for the progress of grapevine breeding. Some results in this field are presented in this paper.

Materials and methods

The experimental work was carried out at the Institute of Viticulture and Enology, Pleven. Five wine varieties bred at the institute were investigated: Storgoziya, Nikopolski mavrud, Pomoriïski biser, Dunavska gamza and Dunavski lazur. The first of these was grafted on Chasselas x Berlandieri 41 B rootstock, each of the other cultivars on three rootstocks: Chasselas x Berlandieri 41 B, Berlandieri x Riparia SO 4 and (Berlandieri x Riparia Kober 5 BB) x (Rupestris Martin) III-102 D[1)], the latter having been developed at the Institute of Viticulture and Enology (DIMITROV 1977, author's certificate no. 23562). During the vegetation period, dry matter accumulation in leaves, pigment content, leaf area, grape yield, as well as other additional characteristics were determined.

Dry matter accumulated in leaves during the day was determined after the method of SACHS (POPOV *et al.* 1957), leaf samples were taken for this purpose at 8. a.m., 12 p.m. and 4 p.m. three times during the vegetation period in phenophases of flowering, onset of grape maturation

[1)] For brevity: 41 B, SO 4, III-102.

(véraison), and maturation. Specific leaf (dry) weight was measured as mg/dm^2. Pigment content (chlorophyll a, chlorophyll b and carotenoids) was determined spectrophotometrically (POCHINOK 1976) during the same phases as mg % (mg per 100 g dry weight). Leaf area per vine was calculated as m^2 (CARBONNEAU 1976; SLAVCHEVA 1983, 1987). Grape yield was measured as kg per grapevine.

The data were statistically processed (MUDRA 1958; BAROV and NAIDENOVA 1969).

Table 1: Specific leaf weight during the day (mg dry wt/dm^2)

Rootstocks		Cultivars				
		Nikopolski mavrud	Pomoriïski biser	Dunavska gamza	Dunavski lazur	Storgoziya
				Flowering		
41 B	I[1])	454.4	494.2	495.4	459.1	469.4
	II[1])	488.8	524.7	522.1	497.8	498.1
	III[1])	500.3	555.5	559.6	521.5	524.9
SO 4	I	451.8	493.0	502.3	467.4	
	II	488.2	526.5	543.3	492.6	
	III	503.1	549.2	566.6	520.6	
III-102	I	469.3	504.2	527.6	469.1	
	II	493.1	537.0	553.0	509.2	
	III	528.0	549.2	573.4	519.5	
				Onset of maturation		
41 B	I	675.9	727.4	717.1	684.5	627.9
	II	708.7	775.4	766.3	721.2	660.6
	III	722.4	767.6	781.4	733.0	665.8
SO 4	I	670.3	718.2	737.6	684.3	
	II	712.8	762.3	781.5	716.5	
	III	728.6	795.2	795.0	724.5	
III-102	I	697.5	757.4	747.8	687.9	
	II	743.2	791.1	790.5	728.2	
	III	746.2	806.0	812.5	738.6	
				Maturation		
41 B	I	675.4	796.0	763.3	700.2	656.8
	II	698.0	825.6	784.5	712.5	694.8
	III	711.4	830.9	801.5	712.9	694.6
SO 4	I	680.5	791.5	798.1	697.1	
	II	712.4	841.5	811.5	708.0	
	III	724.8	820.4	816.5	709.3	
III-102	I	726.6	841.5	811.6	740.9	
	II	766.1	901.5	833.5	768.7	
	III	757.1	868.1	828.2	748.3	

[1]) First (8 a.m.), second (12 p.m.), third (4 p.m.) samples in the day-time.

Results and discussion

In Table 1 data are shown on specific leaf weight at 8 a.m., 12 p.m. and 4 p.m. during flowering, onset of maturation and maturation. The specific weight of leaves increased during the day as a result of their photosynthetic activity irrespective of variety and rootstock. This allowed to use summarized equations for characterization of the general regularities. The dry matter increment of leaves during the day can be described by linear regressions as follows:

Rootstock	Flowering	Onset of maturation	Maturation
41 B	$y = 408.6 + 8.06x$	$y = 629.6 + 8.30x$	$y = 695.7 + 4.46x$
SO 4	$y = 415.1 + 7.74x$	$y = 634.6 + 8.21x$	$y = 717.3 + 3.39x$
III-102	$y = 435.3 + 6.95x$	$y = 657.6 + 7.83x$	$y = 763.7 + 2.88x$

In the equations y is the specific leaf weight, i. e. the leaf dry weight per unit leaf area (mg/dm^2), and x the time of day (h between 8 a.m. and 4 p.m.). During flowering the t-test for the three rootstocks was $t_{exp.} > t_{tab.}$, during onset of maturation this was relevant to 41 B and SO 4 rootstocks, during grape maturation $t_{exp.} < t_{tab.}$. The rate of dry matter accumulation in leaves during the day, i. e. the change in leaf dry weight per unit leaf area per unit time, was highest on 41 B rootstock, and lowest on III-102. The specific leaf weight, in contrast, was greatest on III-102 and lowest on 41 B (significant differences). Furthermore, the dry matter accumulation rate in leaves during the day depended also on the phase; it was highest during onset of maturation and lowest during maturation.

Changes in specific leaf weight during the day can be described by a non-linear regression, polynomial of second degree:

Rootstock	Flowering	Onset of maturation	Maturation
41 B	$y = 324.6 + 22.75x - 0.60x^2$	$y = 464.9 + 37.77x - 1.24x^2$	$y = 612.2 + 18.53x - 0.56x^2$
SO 4	$y = 307.1 + 26.62x - 0.78x^2$	$y = 500.2 + 31.43x - 0.95x^2$	$y = 624.2 + 19.10x - 0.63x^2$
III-102	$y = 311.2 + 28.64x - 0.89x^2$	$y = 456.6 + 42.54x - 1.42x^2$	$y = 435.8 + 58.28x - 2.22x^2$

The meaning of y and x is the same as above.

After differentiating the above-mentioned equations the following was obtained:

Rootstock	Flowering	Onset of maturation	Maturation
41 B	$\frac{dy}{dx} = 22.75 - 1.20x$	$\frac{dy}{dx} = 37.77 - 2.48x$	$\frac{dy}{dx} = 18.53 - 1.12x$
SO 4	$\frac{dy}{dx} = 26.62 - 1.56x$	$\frac{dy}{dx} = 31.43 - 1.90x$	$\frac{dy}{dx} = 19.10 - 1.26x$
III-102	$\frac{dy}{dx} = 28.64 - 1.78x$	$\frac{dy}{dx} = 42.54 - 2.84x$	$\frac{dy}{dx} = 58.28 - 4.44x$

In the equations $^{dy}/_{dx}$ is the rate of dry matter accumulation in leaves during the day ($mg/dm^2 \cdot h$) and x as formerly the time of day between 8 a.m. and 4 p.m. (h). This dry matter accumulation rate depended on the rate of net assimilates production and the rate of their translocation to the other organs. It decreased linearly with time from the morning hours (8 a.m.) towards the afternoon hours (4 p.m.), which was probably due to overcharging the photosynthetic apparatus with assimilates, causing a depression of photosynthesis. The coefficient before x is a measure of the reduction of dry matter accumulation rate in leaves per unit time.

Statistic data processing was complicated by the use of a non-linear regression to describe the change in specific leaf weight during the day. Verification by an F-test did not give better results, so we could satisfy ourselves with a linear regression. Experimental data, however, are better described by a non-linear regression and, provided a sufficiently large number of replicates is available, it is preferable.

Data examination for each variety showed that the already mentioned tendencies remain with little exceptions, so that the use of generalized data proved to be adequate. (Under the aspect of varieties the data will be examined in more detail in another paper.) Highest values of specific leaf weight were obtained for cvs Pomoriïski biser and Dunavska gamza, and lower values were obtained for Dunavski lazur, Nikopolski mavrud and Storgoziya. The differences between the two groups of cultivars were significant ($F_{exp.} > F_{0.001}$). Specific leaf weight is a typical characteristic of variety and rootstock.

In Table 1 it is also seen that the specific leaf weight increased during the vegetation period. Its change could be described by a non-linear regression, as follows:

41 B	$y = 475.1 + 4.870x - 0.0207x^2$	($F_{exp.} = 54.94 > F_{0.001} = 27.00$)
SO 4	$y = 477.9 + 5.047x - 0.0223x^2$	($F_{exp.} = 44.66 > F_{0.001} = 27.00$)
III-102	$y = 486.3 + 5.012x - 0.0199x^2$	($F_{exp.} = 49.12 > F_{0.001} = 27.00$)

In the equations y is the specific leaf weight (mean value from the three measurements during the day) as mg/dm^2, and x the time in days (d) after the earliest date of measuring (in this case during flowering).

When we differentiated the equations, the first derivative of y with respect to x was considered as rate of dry matter accumulation in leaves during the vegetation period. This looked like this:

41 B	$\frac{dy}{dx} = 4.870 - 0.0414x$
SO 4	$\frac{dy}{dx} = 5.047 - 0.0446x$
III-102	$\frac{dy}{dx} = 5.012 - 0.0398x$

In the equations $^{dy}/_{dx}$ is the gain in leaf dry matter, calculated per unit leaf area per unit time ($mg/dm^2 \cdot d$) and x the time in days (d) after florescence. The rate of dry matter accumulation decreased uniformly in the course of time, most slowly on III-102 and most rapidly on SO 4 rootstock. Considered for each cultivar, the results are analogous; the value of $^{dy}/_{dx}$ (average for the vegetation period) was smallest on SO 4 and it was highest on III-102 except for cv. Dunavska gamza, where in general the differences were small.

This fact could be related to the translocation of assimilates toward clusters and other sinks. According to Vasev (1976), interrupted or retarded assimilate flow causes an increase in leaf dry weight and reduces water content and plastid pigment amount. Export of photosynthates from leaves is controlled by the needs of the individual sinks (Stoev and Ivantchev 1977; Orth 1983; Eibach and Alleweldt 1985). The cluster becomes the principal sink for photosynthates produced in the middle third of the shoot after fruit-set during its most intensive growth (Balcar and Hernandez 1988) and particularly at onset of maturation (Stoev and Ivantchev 1977).

From Table 2 it is seen that for all cultivars on SO 4 rootstock a higher yield was obtained mainly at the expense of cluster weight, i. e. reciprocally to the rate of dry matter accumulation in leaves. This shows the correctness of such an approach.

Leaf area correlates to yield ($r = +0.799 > r_{0.01} = 0.684$). For all varieties the leaf area per vine was greatest on SO 4 rootstock, mainly at the expense of the mean area per leaf (Table 3).

Table 2: Grape yield (kg/vine)

Rootstocks	Cultivars				
	Nikopolski mavrud	Pomoriïski biser	Dunavska gamza	Dunavski lazur	Storgoziya
41 B	4.619	5.600	5.844	5.540	7.530
SO 4	6.520	7.304	6.717	6.495	
III-102	5.403	4.864	4.404	5.056	

Table 3: Leaf area (m^2/vine)

Rootstocks	Cultivars				
	Nikopolski mavrud	Pomoriïski biser	Dunavska gamza	Dunavski lazur	Storgoziya
41 B	9.9	9.6	6.8	8.2	13.1
SO 4	12.0	12.2	7.0	12.6	
III-102	10.2	6.3	6.3	5.3	

Table 4: Thickness of the trunk (mm) (A) above and (B) under the graft-union

Rootstocks	Cultivars				
	Nikopolski mavrud	Pomoriïski biser	Dunavska gamza	Dunavski lazur	Storgoziya
			A		
41 B	32.5[1])	32.0	28.5	29.9	32.4
SO 4	34.3	33.6	29.1	31.0	
III-102	32.6	33.6	29.1	31.2	
			B		
41 B	32.7	35.6	33.2	33.3	35.9
SO 4	28.4	28.9	25.7	28.2	
III-102	34.7	35.1	31.1	34.7	

[1]) The data are mean values from 3 years.

As to thickness of the trunk (which is a consumer as well) under the graft-union, it was smallest when the cultivars were grafted on SO 4, probably owing to rival interrelations, i. e. the assimilates

Table 5: Pigment contents in the leaves (mg/100 g dry wt)

Rootstocks	Cultivars				
	Nikopolski mavrud	Pomoriïski biser	Dunavska gamza	Dunavski lazur	Storgoziya
			Chlorophyll a		
41 B	415[1])	406	382	406	497
SO 4	477	439	383	435	
III-102	434	408	369	391	
			Chlorophyll b		
41 B	138	130	114	128	159
SO 4	141	154	108	126	
III-102	124	119	107	116	
			Carotenoids		
41 B	209	204	191	198	238
SO 4	239	216	198	213	
III-102	229	218	194	195	

[1]) The data are mean values from the three measurements in phenophases of flowering, onset of grape maturation, and maturation.

were distributed predominantly in the overground part and besides an irregular thickening of both components, rootstock and scion, occurred (Table 4). In contrast, on III-102 rootstock, probably owing to the presence of a smaller consumer (cluster) a greater portion of dry matter was accumulated in the leaves and subsequently in the perennial parts, which corresponds to some results obtained by DIMITROV (1984, unpublished data).

The contents of chlorophyll a, chlorophyll b and carotenoids in leaves are shown in Table 5. The data concerning rootstock III-102 are from 2 years. The highest pigment content was characteristic of cv. Nikopolski mavrud, followed by Pomoriïski biser, the lowest of cv. Dunavska gamza; on 41 B rootstock, the pigment content was greatest for cv. Storgoziya. Cv. Pomoriïski biser was not significantly different ($F_{exp.} < F_{0.05}$) from Nikopolski mavrud in regards to pigment contents, but the differences were significant for Dunavski lazur and Dunavska gamza ($F_{exp.} > F_{tab.}$). For all varieties the total content of pigments was highest on SO 4 rootstock, mainly at the expense of chlorophyll a and the carotenoids.

Pigment contents continuously decreased during the vegetation period. This could be expressed for chlorophyll a by a linear regression, as follows:

41 B	$y = 530 - 1.840x$	$(t_{exp.} = 6.523 > t_{0.001} = 5.408)$
SO 4	$y = 515 - 1.158x$	$(t_{exp.} = 7.163 > t_{0.001} = 5.408)$
III-102	$y = 571 - 2.302x$	$(t_{exp.} = 7.328 > t_{0.01} = 4.604)$

In the equations y is the content of chlorophyll a (mg/100 g dry weight) and x the time (d) after florescence.

Analogous equations were obtained for chlorophyll b:

41 B	$y = 163 - 0.509x$	$(t_{exp.} = 5.052 > t_{0.01} = 3.499)$
SO 4	$y = 156 - 0.325x$	$(t_{exp.} = 2.287 < t_{0.05} = 2.365)$
III-102	$y = 164 - 0.634x$	$(t_{exp.} = 2.309 < t_{0.05} = 2.776)$

where y is the content of chlorophyll b and x as above.

For the carotenoids:

41 B	$y = 248 - 0.685x$	$(t_{exp.} = 3.686 > t_{0.01} = 3.499)$
SO 4	$y = 251 - 0.491x$	$(t_{exp.} = 2.775 > t_{0.05} = 2.365)$
III-102	$y = 273 - 0.871x$	$(t_{exp.} = 5.496 > t_{0.01} = 4.604)$

And, finally, jointly for chlorophylls + carotenoids:

41 B	$y = 926 - 2.868x$	$(t_{exp.} = 5.788 > t_{0.001} = 5.408)$
SO 4	$y = 921 - 1.973x$	$(t_{exp.} = 6.479 > t_{0.001} = 5.408)$
III-102	$y = 1002 - 3.794x$	$(t_{exp.} = 7.503 > t_{0.01} = 4.604)$

Therefore, with all the three rootstocks pigment contents in leaves decreased during the vegetation period. This change was not observed for chlorophyll b (SO 4 and III-102 rootstocks).

It should be noted that during flowering pigment contents in the leaves of the cultivars, grafted on III-102 rootstock, was higher compared to the other two rootstocks, but at the end of the maturation phase it was already lower. Obviously on III-102 rootstock conditions were created for faster shoot maturation, which is one of the premises for its better frost resistance (Slavcheva, unpublished data; Popov 1988).

A negative correlation ($r > r_{0.001}$) existed between the specific leaf weight and the pigment contents in leaves, both characteristics depended on the time (date), i. e. they changed during the vegetation period.

In conclusion, differences were established in the investigated physiological and other characteristics in relation with variety and rootstock. The obtained knowledge can be utilized in grapevine breeding.

Acknowledgements

The valuable technical assistance of Mrs. A. Gadevska and Mr. T. Trifonov is gratefully acknowledged.

References

Balcar, I.; Hernandez, I.; 1988: Translocation of photosynthate in grapevine shoots during the growth period. Vitis **27**, 13-20.

Barov, V.; Naidenova, P.; 1969: Statistical Methods for Field and Vegetation Experiments [Bulg.]. Zemizdat, Sofiya.

Carbonneau, A.; 1976: Principes et méthodes de mesure de la surface foliaire. Essai de caractérisation des types de feuilles dans le genre *Vitis*. Ann. Amélior. Plantes **26**, 327-343.

Eibach, R.; Alleweldt, G.; 1985: Einfluß der Wasserversorgung auf Wachstum, Gaswechsel und Substanzproduktion traubentragender Reben. III. Die Substanzproduktion. Vitis **24**, 183-198.

Mudra, A.; 1958: Statistische Methoden für Landwirtschaftsversuche. Paul Parey Verlag, Berlin, Hamburg.

Orth, C.; 1983: Einfluß der Wasserversorgung auf die Assimilattranslokation bei Reben. Diss., Univ. Hohenheim. [Ref.: Vitis **23**, 1 C 3].

Pochinok, Kh. N.; 1976: Methods of Biochemical Analysis of Plants [Russ.]. Naukova Dumka, Kiev.

Popov, K.; 1988: Investigation on the influence of rootstock III-102 D on the vegetative and reproductive growth of grapevine cv. Merlot [Bulg.]. Lozar. Vinar. **37** (3), 20-22.

-- -- ; Docheva-Popova, R.; Georgiev, G. Kh.; Gushterov, G. K.; 1957: A Practical Handbook of Plant Physiology [Bulg.]. Nauka i Izkustvo, Sofiya.

SLAVCHEVA, T.; 1981: Influence of Some Ecological Factors of Grapevine Photosynthesis [Bulg.]. Thesis, Inst. Viticulture and Enology, Pleven.

-- -- ; 1983: Theoretical curves for determining the leaf area in some grapevine varieties [Bulg.]. Grad. Lozar. Nauka **20** (3), 89-97.

-- -- ; 1987: The effects of planting density and plant formation on the leaf area of cv. Dimiat grapevines [Bulg.]. Rasteniev dni Nauki **24** (12), 92-98.

-- -- ; 1988: The productivity of grapevine (*V. vinifera* L.) and the methods of cultivation. Intern. Symp. Plant Mineral Nutrition and Photosynthesis, Varna, 4.-10.10.1987, Vol. II, 310-314. Bulgarian Academy of Sciences, Sofiya.

STOEV, K. D.; IVANTCHEV, V.; 1977: Données nouvelles sur le problème de la translocation descendante et ascendante des produits de la photosynthèse de la vigne. Vitis **16**, 253-262.

-- -- ; SLAVTCHEVA, T.; 1982: La photosynthèse nette chez la vigne (*V. vinifera* L.) et les facteurs écologiques. Connaiss. Vigne Vin **16**, 171-185.

VASEV, V.; 1974: Influence of the flow of assimilates on the structure of the leaves as photosynthetic apparatus [Bulg.]. In: Plant Physiology, Vol. **2**, 121-133. Georgi Dimitrov Agricult. Acad. Sofiya.